

Mulkerin Associates Inc.

Accelerating CNS



Computer Networks & Software, Inc.

Large-Scale Controller Pilot Data Link Communications (CPDLC) Emulation Testbed

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Background



- Accelerating CNS
- Impact of data link traffic loads on the National Airspace System (NAS) communications infrastructure is not well known.
- FAA has established communications performance requirements for CPDLC.
- NASA's Glenn Research Center has developed an emulation and test facility.
 - Provides means of observing the operation of large-scale aeronautical data link communications using different subnetworks.
 - Enables study of data link interactions and capacity of NAS infrastructure to support CPDLC traffic.



CPDLC Performance Requirements Accelerating CNS



• FAA Requirements for End-to-End Transfer Delay

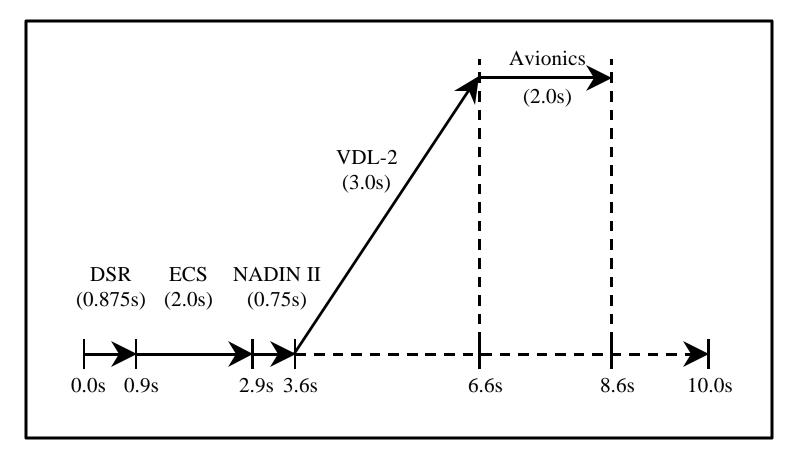
Domain	Mean End-to-End Transfer Delay	95% End-to-End Transfer Delay	99.996% End-to-End Transfer Delay
Terminal	5 sec	8 sec	12.5 sec
En Route	10 sec	15 sec	22 sec

Source: FAA Initial Requirements Document for Controller Pilot Data Link Communications (CPDLC) Services, 22 Jun 98



End-to-End Delay - CPDLC IA Budget

FAA CPDLC-IA Specification for En Route Delay



Mean Transfer Delay Time Budgets



GRC's Emulation and Test Facility



- Support realistic message traffic testing of multiple subnetworks
 - VDL Mode 2
 - VDL Mode 3
 - SATCOM
 - Others
- Hardware
 - VDL Mode 2 subnetwork
 - » ARINC VDL Mode 2 ground station
 - » Air/ground routers
 - » Data link radios
 - PCs for the emulation software
 - Local Area Network



GRC's Emulation and Test Facility



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Software

- Aeronautical Telecommunications Network (ATN) emulation software
 - Context Management (CM)
 - Controller Pilot Data Link Communications (CPDLC)
 - Developed by Computer Networks & Software, Inc.(CNS)
- ISO compliant transport and network layer protocols (TP4/CLNP)
 - Open Networks Engineering (ONE) OSI Foundation
 v 4.46
- Windows NT OS



Large-Scale CPDLC Emulation



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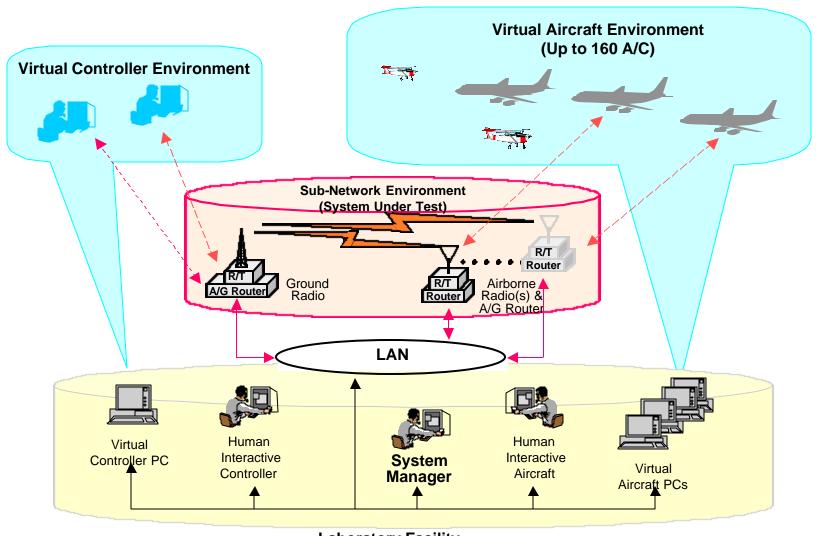
Distributed ATN data link communications emulator

- 160+ aircraft
- Multiple controllers
- System manager: Single point of control and test data collection and reporting
- ATN SARPs compliant Baseline 1 CPDLC message set
 - 105 uplink and downlink messages



Virtual Aircraft Emulation

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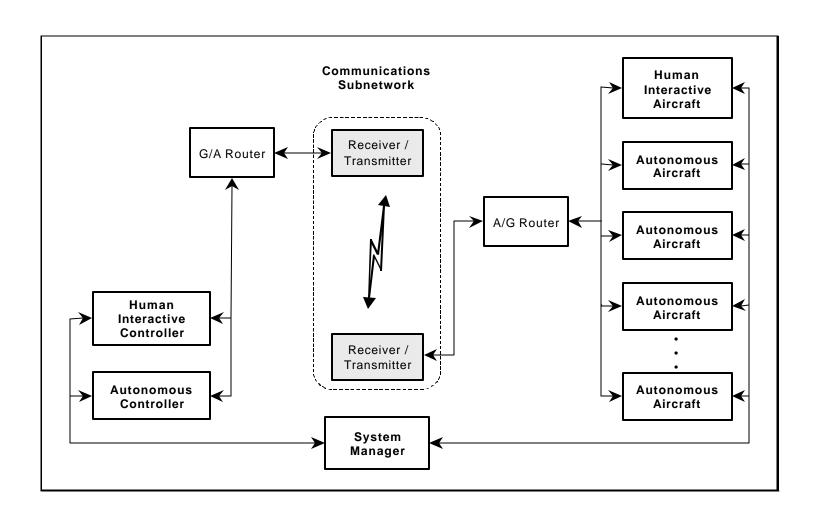


Laboratory Facility



Functional Configuration







Aircraft/Controller Functionality

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GUIs

- Emulates Generic ATC Workstation
- Emulates Generic MCDU
- Message Alerting & Display
- Message Selection & Composition
- · Actions Taken Indicators
- "Free Play" CPDLC with ATSP
- Controller Display has Full Data Blocks

Human Interactive Aircraft & Controller

- "Human in the Loop" Testing
 - User Configuration, Initialization and Experiment
 - Responses Based on Received Message
- Monitored by System Manager
- Communications:
 - ATN Compliant (TP4/CLNP)
 - Between Interactive Controller and Aircraft via ATN Subnetwork
 - With System Manager
- Automatically Saves all Configuration and Experiment Data

CM Services

- CM Logon
- CM End
- CM Abort

CPDLC Services

- CPDLC Start Request
- CPDLC Message Service
- CPDLC End Service Request

CPDLC Messages

- SARPs Compliant CPDLC
 - 69 Uplink Messages
 - 36 Downlink Messages
- ADLS Baseline 1 Message Set
- Message Element Concatenation

Autonomous Aircraft & Controller

- Up to 160 Aircraft Emulated
- Script Driven
 - Timed Aircraft Requests
 - Timed Controller Instructions
 - Automated Response to Requests based on Received Message
- Managed, Controlled and Monitored by System Manager
- Communications:
 - ATN Compliant (TP4/CLNP)
 - Between Aircraft and Controller via ATN Subnetwork
 - With System Manager
- Automatically Saves all Configuration and Experiment data



System Manager Functionality

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Autonomous Operations

- Initiated and Controlled by System Manager
- Not Affected by Human Interactive Operations

System Initialization

 Distributes Configuration Data to Workstations

Data Transfer

- Online Real Time Status
- Offline Post-Experiment File Transfer of Aircraft and Controller Files for Data Reduction

System Control

Start and Stop Experiment

Experiment Scripting

- User Constructs Scenario Scripts
- Supports Aircraft Departure to Arrival Profile
- Supports Background Loading with CPDLC Messages
- ATN SARPs Compliant Messages
- Script Library
- Prints Scripts in Human Readable Form

Monitor

- · Communications Delay Measurements
- Communications Status of Each Workstation
- Error Message Status

Script Monitoring and Display

- Monitor Scenario Progress on System Manager Display
- Monitor Status of Individual Autonomous Aircraft Script Execution

Data Reduction

· Processes Data for use in Reporting

System Configuration

- Select Workstations for Experiment
- Select Controller Workstations
- Assign Aircraft for Each Workstation
- Assign Script to Each Aircraft
- Assign 24-bit Address to Each Aircraft
- Assign Facility Designation to Controller
- Assign Unique NSAPs to Each Aircraft and Controller
- Enter Experiment Start and Stop Times

Reporting

- User Selectable Reports
- · Display, Save, and Print Reports
- On-line Reports
 - End-to-End Delay
 - Error Messages
- Off-line Reports
 - Experiment Summary
 - Message Transmitted List
 - Message Received List
 - Master Message List
 - End-to-End Delay
 - Error Messages

 - Related Events



Aircraft Display

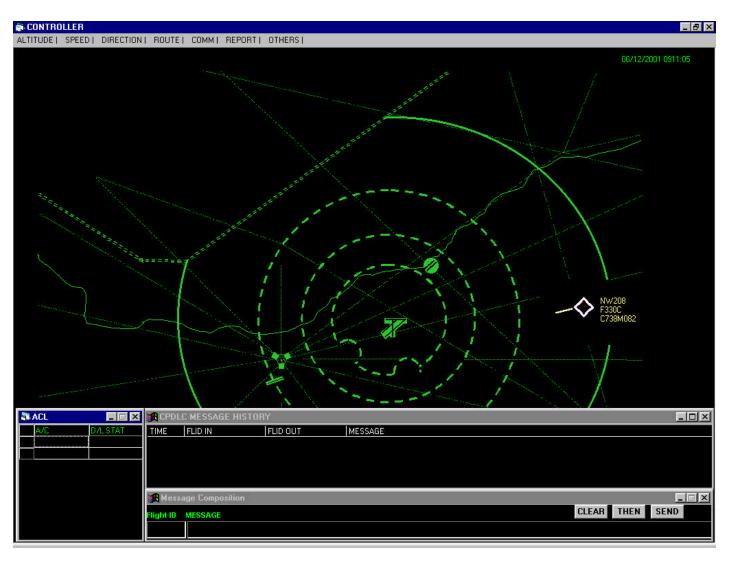
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En Route Controller Display



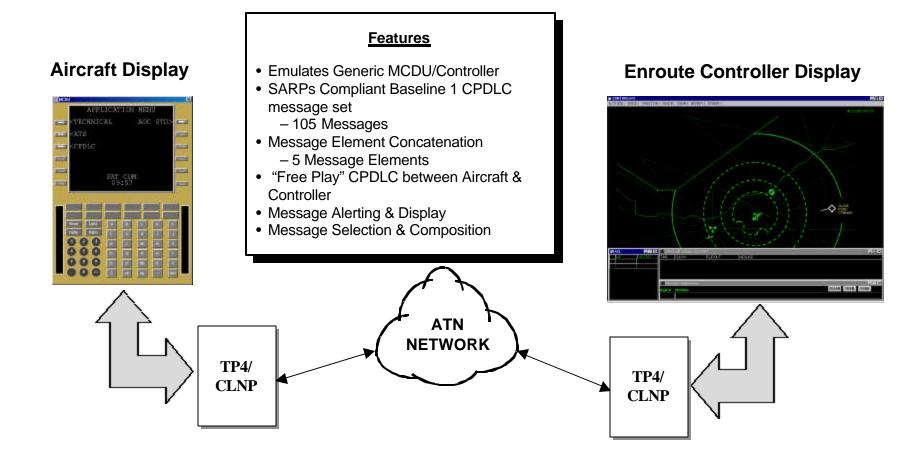




Human Interactive Message Exchanges

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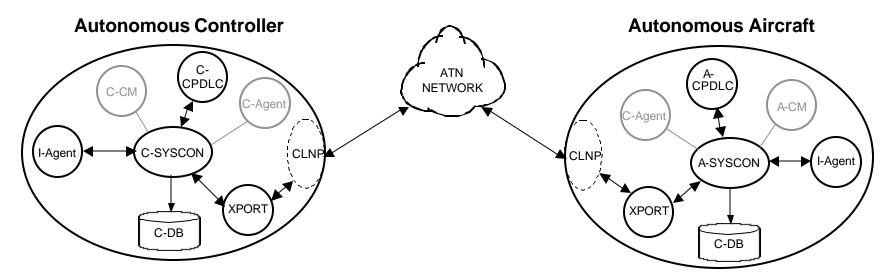


Manual Message Input and Response



Autonomous Message Exchange





- Up to 160 autonomous aircraft driven by intelligent agents
- Multiple autonomous controllers
- Automatic, script-driven aircraft/controller message exchange
- Responses reactive to subnetwork transport delays ("freeplay")
- Experiment performance online and offline data collection



Aviation Communication System Design

Accelerating CNS Autonomous Human Aircraft (AA) **Interactive Aircraft** C/I-Agent C-Agent A-GUI $\mathbf{A}\mathbf{A}$ $\mathbf{A}\mathbf{A}$ $\mathbf{A}\mathbf{A}$ (HIA) CP-AE CM-AE CP-AE CM-AE TP4 TP4 CLNP CLNP 802.3 802.3 CLNP **ATN Router** VDL-2 V/L/D ASIP - AVLC Simple 802.3 **ASIP** Interface Protocol 100M Switch WB-3 V/L/D - VME/LME/DLE ARINC-429 WB-3 - Williamsburg V-3 **VDR** 429 - ARINC 429 MAC IF ASIP I-Agent - Intelligent Agent **VDR** WB-3 VDL-2 MAC C-Agent - Com. Agent VDL-2 D8PSK **Human Interactive** Subnet Aircraft (HIA) C-Agent C-GUI (C/I-Agent) **ATN Router** MGR-APPs CM-AE CP-AE TP4 TP4 CM-AE CP-AE **CLNP CLNP VDR** TP4 802.3 802.3 **CLNP** 802.3 100M Switch

= System Manager Data Channel

Printer

System

Manager

Human Interactive

Controller (HIC)

Autonomous

Controller (AC)



Summary



- GRC's large-scale CPDLC emulation testbed provides the capability to study the impact of data link traffic loads on the NAS communications infrastructure.
- End-to-end ATN message (CM and CPDLC) emulation provides the means to assess the number of aircraft that a subnetwork can support and meet the FAA's performance goals.



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